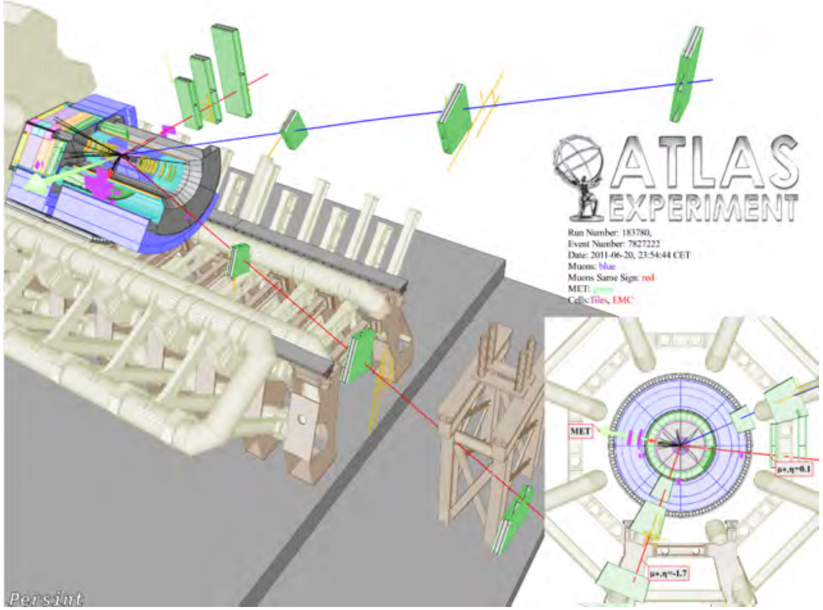
Search for new physics in the same-sign dilepton final states with ATLAS detector



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Motivation

- Many new physics models to produce same-sign leptons in the final state.
  - Supersymmetry
  - Universal extra dimensions
  - Left-right symmetric models
  - Higgs triplet models
  - Little Higgs models
  - Seesaw models
  - Vector-like quark models
- We search for inclusive same-sign leptons to minimize the model dependence.
  - JHEP12(2012)007 (arXiv:1210.4538[hep-ex])
- We also look for doubly-charged Higgs.
  - Eur.Phys.J.C72(2012)2244 (arXiv:1210.5070[hep-ex])

Tight lepton selection

- Tight criteria for electron and muon identification.
- Cuts on both longitudinal (z_0) and transverse (d_0) impact parameters.
  - $|z_0 \sin\theta| < 1\text{mm}$
  - $|d_0|/\sigma(d_0) < 3$
- Isolation cuts:
  - Select leptons isolated from other activity.
  - Isolation variable = sum of momentum or energy around the lepton.

Loose event selection

	Selection Criteria
Primary vertex	3 or more tracks
Same-sign pair(s)	2 or more electron(s) and/or muon(s) with same charge.
Low mass resonance removal	M(ll) > 15 GeV

- 3-channels: ee, eμ, μμ
- 2011, 7TeV data, 4.7fb-1
- Single lepton triggers were used.

- All plots are taken from
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2012-13/
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2012-18/

Backgrounds

- Prompt backgrounds:
  - WZ, ZZ, ttbarW, ttbarZ, same-sign WW.
  - Estimated from MC simulations.
- Charge flip and photon conversion (electron):
  - Main source is trident events:
    - $e^+ \rightarrow e^+\gamma \rightarrow e^+e^+e^-$ when this e^- carry the most of p_T of the original e^+
  - Estimated from MC simulations:
    - Drell-Yan(Z*), ttbar, WW, Wgamma
  - Scale factor is derived by comparing to data in Z-peak region.
- Non-prompt/Fake backgrounds:
  - Semileptonic b and c quark decay
  - K and pi decay in flight
  - Jet faking a lepton

Fake factor method

- Data driven method to estimate the non-prompt/fake background.

	Satisfy isolation	Fail isolation
Data which satisfy signal selection	**Signal region**	**Signal side band (Fake dominant)**
Fake dominant sample	Fake which satisfy signal selection	Fake which fail isolation

- Calculate fake factors from fake dominant samples (di-jet samples).
- Fake factor = (fake which pass signal selection)/(fake which pass fake selection).
  - Fake selection = fail isolation cuts.
- Apply the fake factor to the data:
  - Count fakes in the signal sideband region.
  - Then apply the fake factor to estimate the number of fakes in the signal region.

Fake factor method

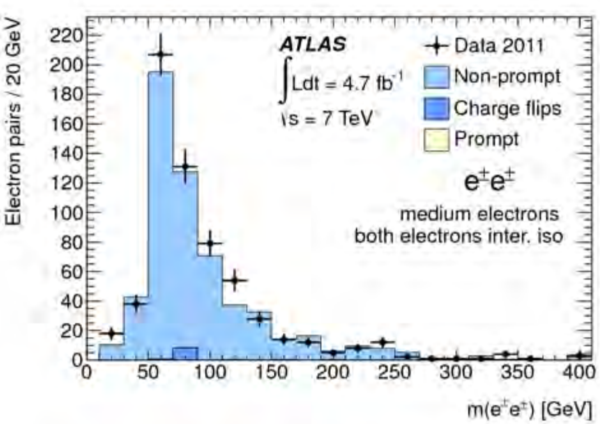
	Satisfy isolation	Fail isolation
Data which satisfy signal selection	**Signal region**	**Signal side band (Fake dominant)**
Fake dominant sample	Fake which satisfy signal selection	Fake which fail isolation

- Key assumption is:
  Fake factor (= the ratio of left/right) is the same both in signal like region and fake dominant sample
- This is the source of systematic errors.

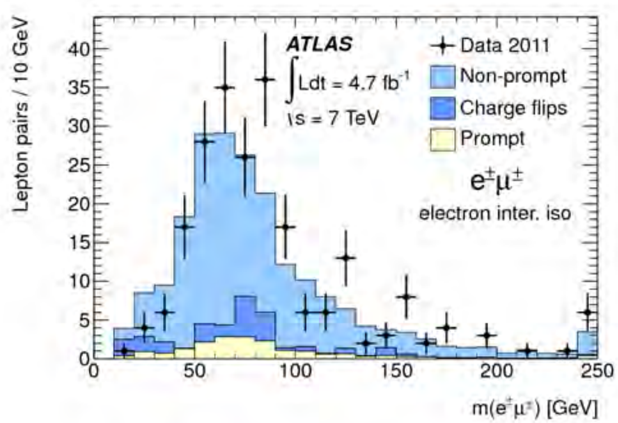
Fake control regions

- We check the validity of our fake factor method using fake control regions.
- We select the signal sideband region dominated by non-prompt/fakes.
  - Sideband = looser particle ID, reversed impact parameter cut, reversed isolation cuts.
- Good agreement between data and expectation

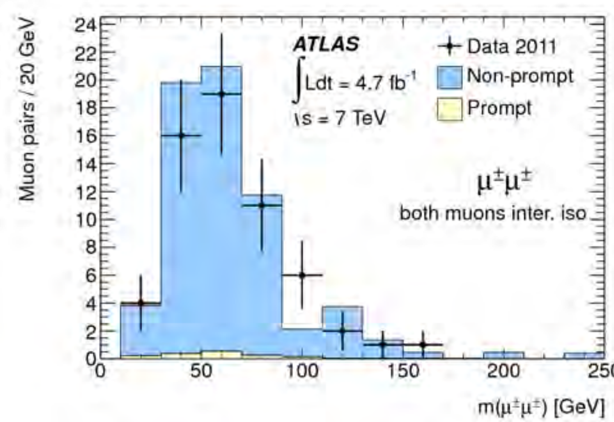
ee



eμ



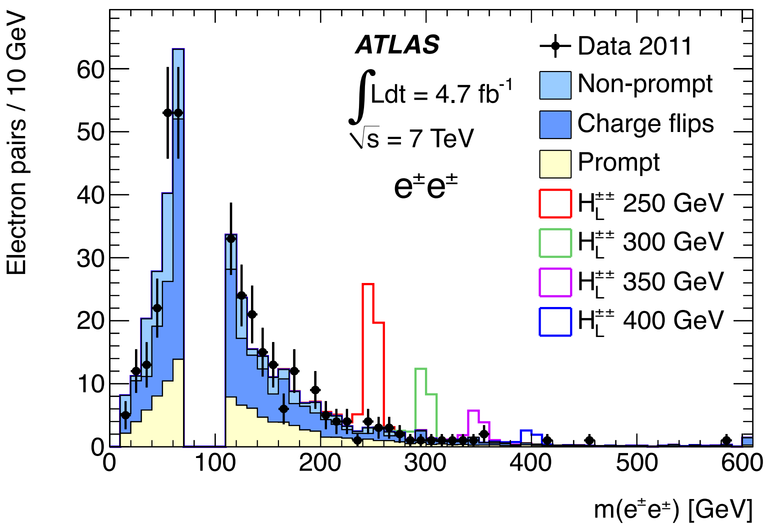
μμ

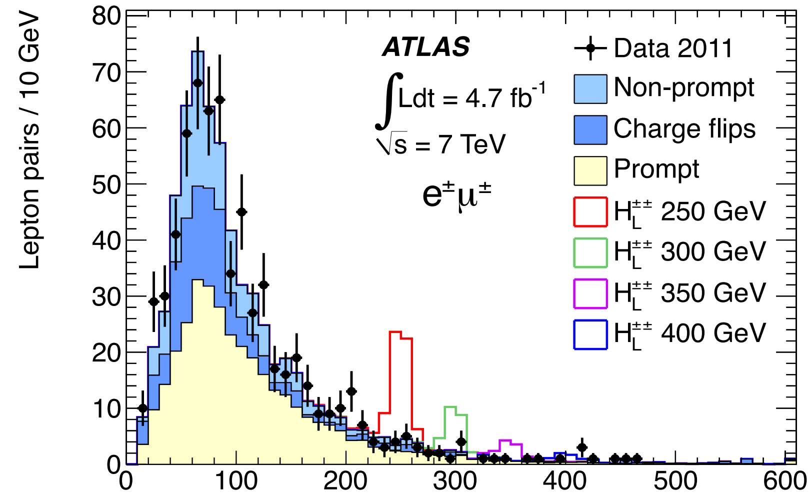


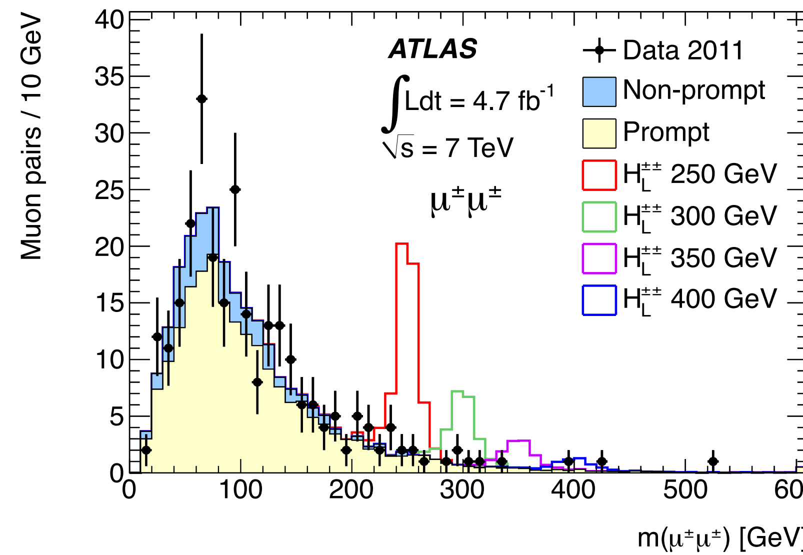
Systematic Uncertainties

- Non-prompt background (Fake)
  - Limited data statistics, fake estimate : 15-100%
- Charge-flip background
  - Scale factor, MC cross section etc. : ~10%
- Prompt background
  - Lepton ID efficiency : ~3%
  - MC cross section : ~10%
- Luminosity : 3.9%

Signal regions





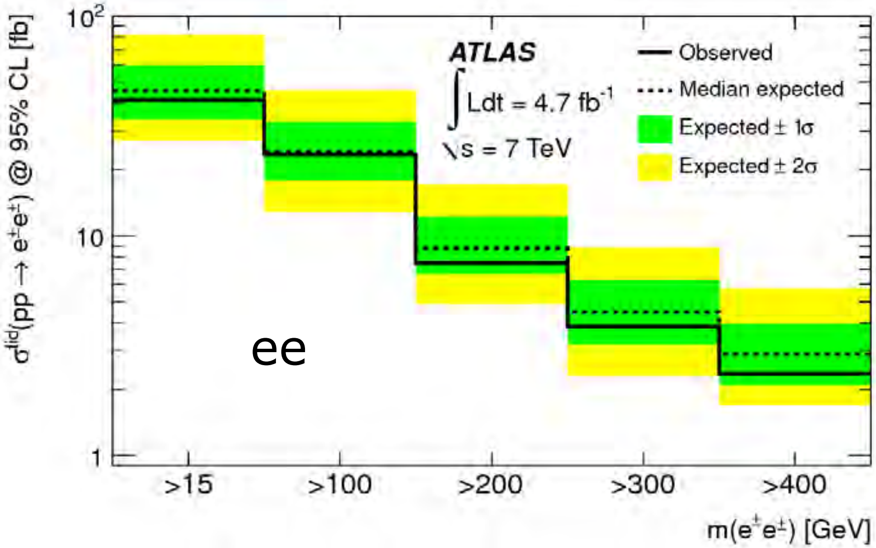


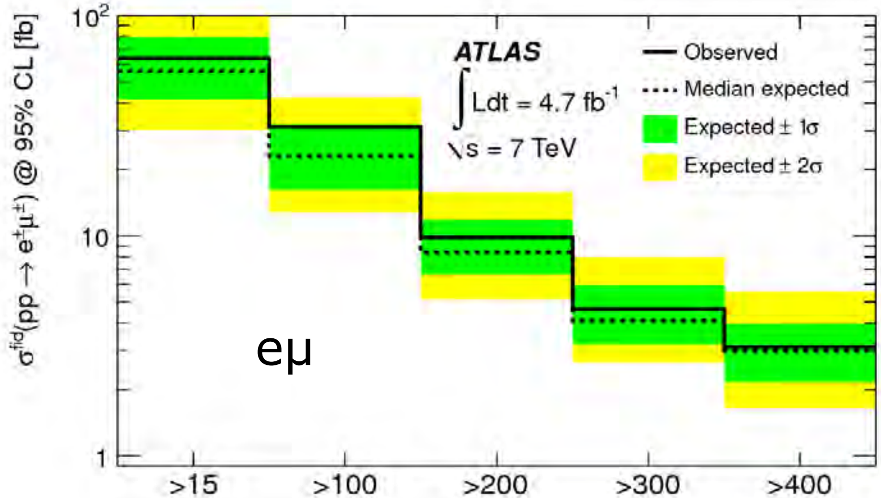
No significant deviation from expected background.
No significant bumps, no overall excess.

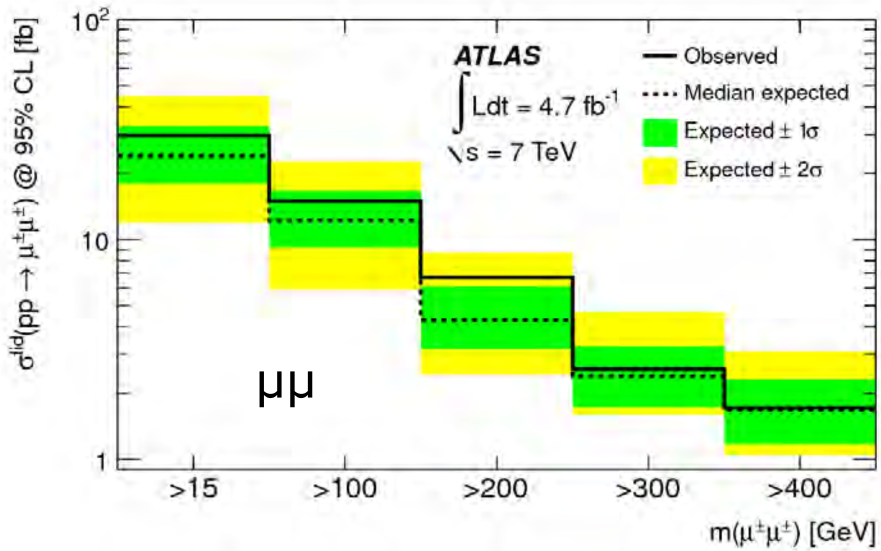
Fiducial cuts

- We set fiducial cuts to reduce model dependence in selection efficiency.
- Fiducial cuts are the same cuts as the selection cuts but with truth variables (so that theorists can reproduce cuts).
- Efficiency variation between different models gets smaller after fiducial cuts.
- We take the lowest efficiency to be conservative.
    - ee: 43%, eμ: 55%, μμ: 59%

Fiducial cross section limits



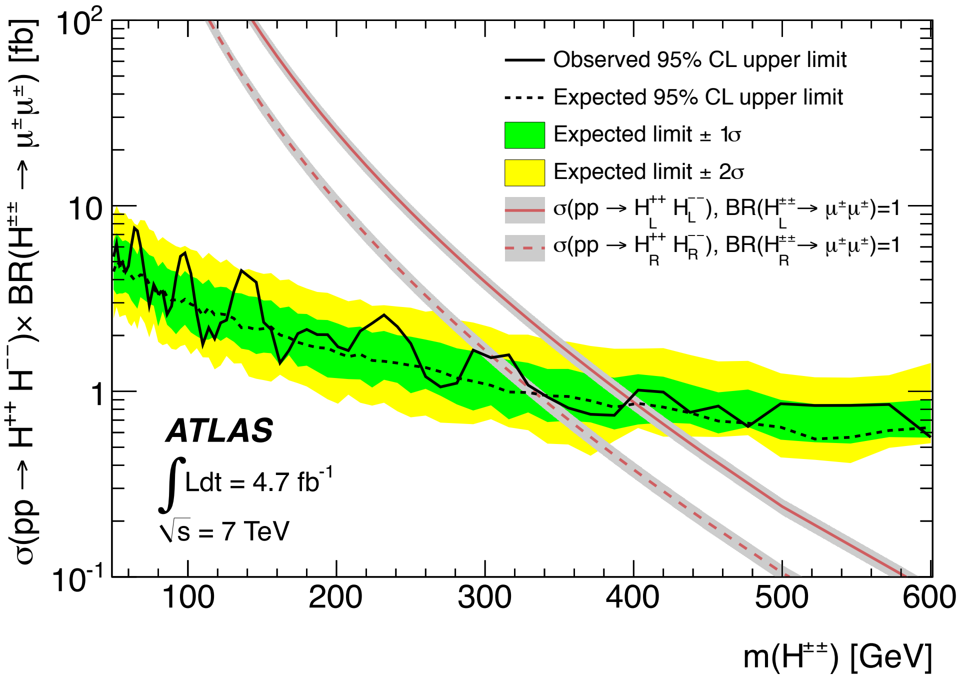




- μμ is the best channel

Limits on doubly-charged Higgs

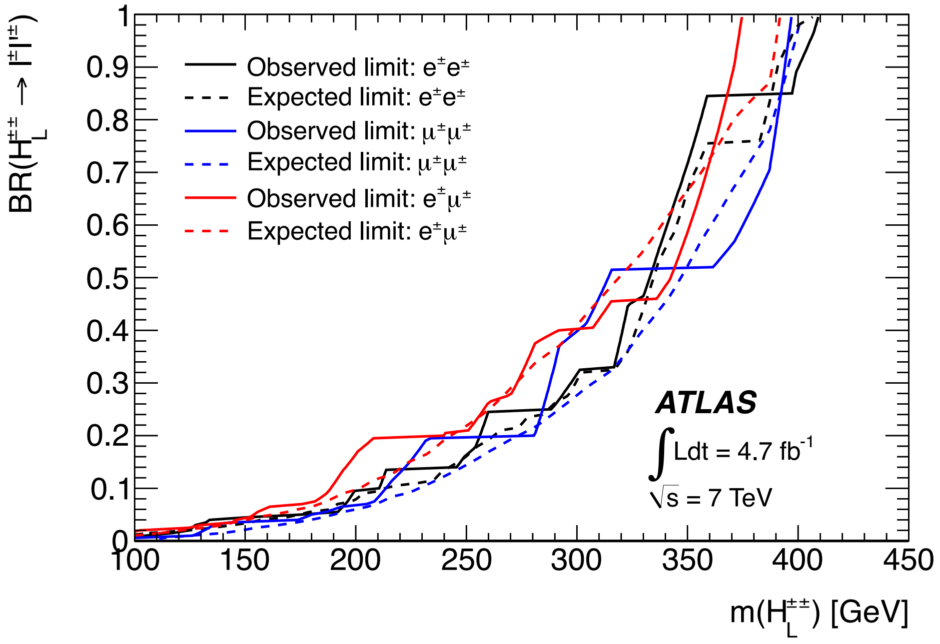
- Doubly charged Higgs can be pair produced:
  - $pp \rightarrow H^{++}H^{--}$
- Doubly charged Higgs decays to two same-sign leptons: $H^{++} \rightarrow l^{+}l^{+}$



μμ-channel

Mass limits vs Branching Ratio

$BR(H_L^{\pm\pm} \to \ell^{\pm}\ell'^{\pm})$	95% CL lower limit on $m(H_L^{\pm\pm})$ [GeV]					
	$e^{\pm}e^{\pm}$		$\mu^{\pm}\mu^{\pm}$		$e^{\pm}\mu^{\pm}$	
	exp.	obs.	exp.	obs.	exp.	obs.
100%	407	409	401	398	392	375
33%	318	317	317	290	279	276
22%	274	258	282	282	250	253
11%	228	212	234	216	206	190



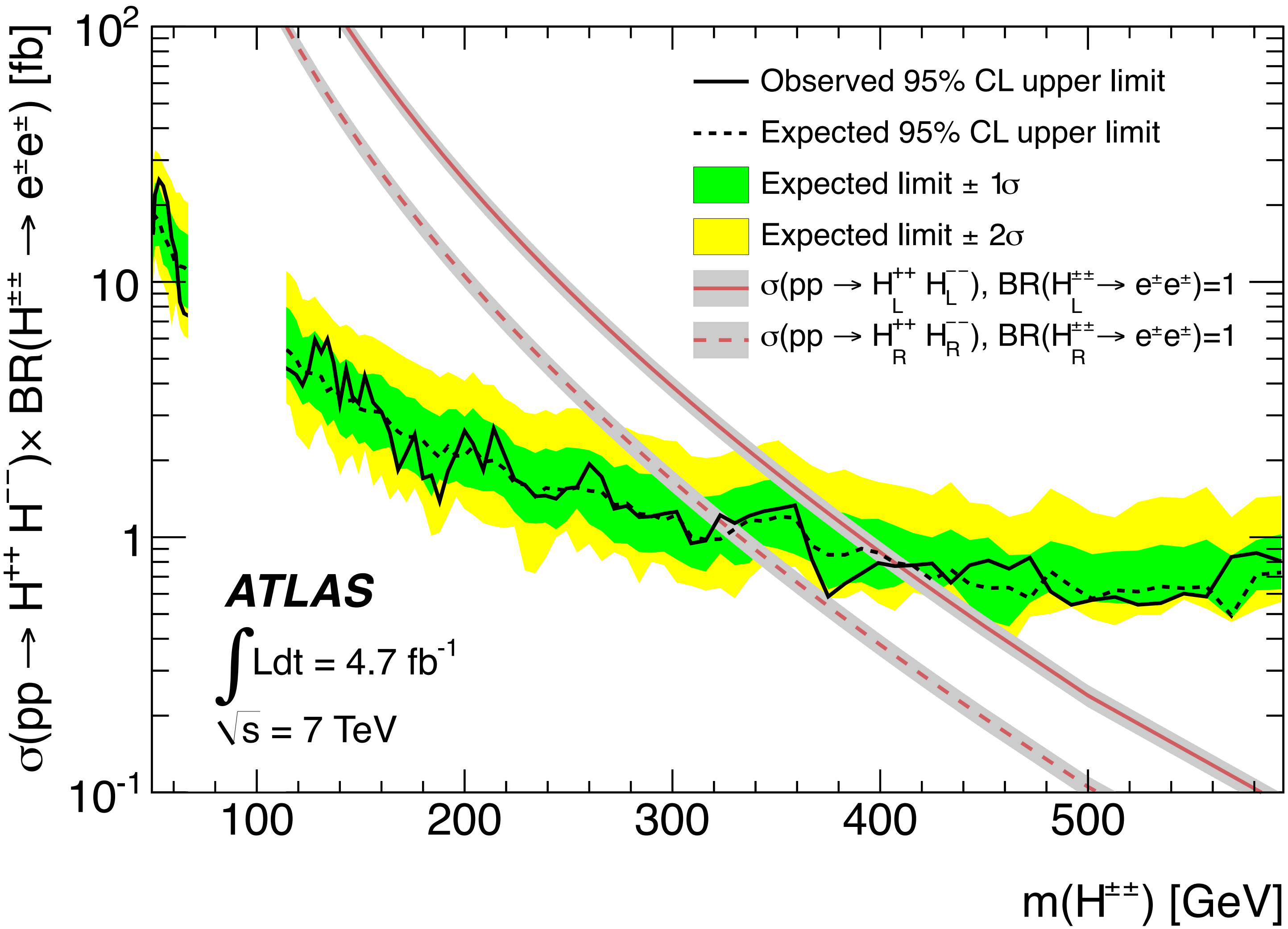
Conclusion and prospects

- Same-sign dilepton final states are searched.
- Good estimates for the main backgrounds:
  - Prompt, charge-flip, non-prompt/fake
- No excess is observed and fiducial cross section limits are set.
  - As a function of dilepton mass.
- Doubly-charged Higgs mass limits are set.
  - Best mass limits as of 2013
- 2012, 8TeV, 20 fb-1 data is under analysis. Results will be made public in July.
  - Big improvements are expected; sensitivity in the doubly-charged Higgs mass increase by ~100GeV.

Back up: Tight lepton selection

	Electron	Muon
Particl ID etc.	isEM tight++	Staco muon, Charge: $Q_{ID} = Q_{MS}$
Leading p_T	25 GeV	25 GeV
Subleading p_T	20 GeV	20 GeV
Eta	$\|\eta\|<2.47$, excluding $1.37<\|\eta\|<1.52$	$\|\eta\|<2.5$
Impact parameter	$\|z_0 \sin\theta\|<1$mm	$\|z_0 \sin\theta\|<1$mm
	$\|d_0\|/\sigma(d_0) < 3$	$\|d_0\|<0.2$mm, $\|d_0\|/\sigma(d_0) < 3$
Track isolation	ptcone30/E_T < 0.1	ptcone40/p_T < 0.06
Calo isolation	Etcone20 < 3+0.037(E_T-20)	
Overlap removal	$\Delta R(e,\mu)>0.05$ $\Delta R(e,jet)>0.40$	$\Delta R(\mu,jet)>0.40$

Back-up: ee-channel



Back-up: eμ-channel